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**Practitioner's Docket No.** AP9714

CHAPTER II

# TRANSMITTAL LETTER
# TO THE UNITED STATES ELECTED OFFICE (EO/US)

## (ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

| PCT/EP00/08989 | 14/Sept/2000 | 15/Sept/1999 |
|---|---|---|
| INTERNATIONAL APPLICATION NO. | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED |

Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle
TITLE OF INVENTION

Hans Bleckmann; Marius Goslar
APPLICANT(S)

**Box PCT**
**Assistant Commissioner for Patents**
**Washington D.C. 20231**
**ATTENTION: EO/US**

*NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 20 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.*

***WARNING:*** *Where the items are those which can be submitted to complete the entry of the international application into the*

**CERTIFICATION UNDER 37 C.F.R. 1.10***
*(Express Mail label number is **mandatory**.)*
*(Express Mail certification is optional.)*

I hereby certify that this correspondence and the documents referred to as attached therein are being deposited with the United States Postal Service on this date 3/15/02, in an envelope as "Express Mail Post Office to Addressee," Mailing Label Number EV051019227US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

Joyce Krumpe
*(type or print name of person mailing paper)*

Joyce Krumpe
**Signature of person mailing paper**

***WARNING:*** *Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.*

****WARNING:*** *Each paper or fee filed by "Express Mail" **must** have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. 1.10(b).*
*"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will **not** be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.*

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*national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. §1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing - See 37 C.F.R. §1.8.*

*NOTE: Documents and fees must be clearly identified as a submission to enter the national state under 35 USC 371 otherwise the submission will be considered as being made under 35 USC 111. 37 C.F.R. § 1.494(f).*

1. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. 371:

    a. [X] This express request to immediately begin national examination procedures (35 U.S.C. 371(f)).

    b. [X] The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

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2.Fees

| CLAIMS FEE | (1) FOR | (2) NUMBER FILED | (3) NUMBER EXTRA | (4) RATE | (5) CALCULATIONS |
|---|---|---|---|---|---|
| [ ]* | TOTAL CLAIMS | 13 - 20 = | | x $ 18.00 = | $ |
| | INDEPENDENT CLAIMS | 2 - 3 = | | x $ 84.00 = | |
| | MULTIPLE DEPENDENT CLAIM(S) (if applicable) + $280.00 | | | | |
| BASIC FEE** | [ ] U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY<br>Where an International preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO:<br>[ ] and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(2) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 CFR 1.492(a)(4)) .......... $100.00<br>[ ] and the above requirements are not met (37 CFR 1.492(a)(1)) ........................................................ $710.00<br><br>[X] U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY<br>Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO:<br>[ ] has been paid (37 CFR 1.492(a)(2)) .......................... $740.00<br>[ ] has not been paid (37 CFR 1.492(a)(3)) .................... $1040.00<br>[X] where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 CFR 1.492(a)(5)) .......................... $890.00 | | | | |
| | Total of above Calculations | | | | = 890.00 |
| SMALL ENTITY | Reduction by ½ for filing by small entity, if applicable. Affidavit must be filed. (note 37 CFR 1.9, 1.27, 1.28) | | | | - |
| | Subtotal | | | | 890.00 |
| | Total National Fee | | | | $ 890.00 |
| | Fee for recording the enclosed assignment document $40.00 (37 CFR 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET". | | | | |
| TOTAL | Total Fees enclosed | | | | $ 890.00 |

*See attached Preliminary Amendment Reducing the Number of Claims.

i. [ ] A check in the amount of ___________ to cover the above fees is enclosed.

ii. [X] Please charge Account No. 18-0013 in the amount of $ 890.00. A duplicate copy of this sheet is enclosed.

***WARNING:* *"To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).*

*WARNING:* *If the translation of the international application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office. 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.*

3. [X] A copy of the International application as filed (35 U.S.C. 371(c)(2)):

*NOTE:* *Section 1.495 (b) was amended to require that the basic national fee and a copy of the international application must be filed with the Office by 30 months from the priority date to avoid abandonment "The International Bureau normally provides the copy of the international application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.*

a. [X] is transmitted herewith.

b. [ ] is not required, as the application was filed with the United States Receiving Office.

c. [ ] has been transmitted

i. [ ] by the International Bureau.
Date of mailing of the application (from form PCT/IB/308): __________.

ii. [ ] by applicant on _______.
Date

4. [X] A translation of the International application into the English language (35 U.S.C. 371(c)(2)):

a. [X] is transmitted herewith.

b. [ ] is not required as the application was filed in English.

c. [ ] was previously transmitted by applicant on _________________.
Date

d. [ ] will follow.

5. [ ] Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. 371(c)(3)):



[redacted]

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NOTE: *The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.*

a. [ ] are transmitted herewith.
b. [ ] have been transmitted
  i. [ ] by the International Bureau.
  Date of mailing of the amendment (from form PCT/IB/308): __________.
  ii. [ ] by applicant on _______.
  Date
c. [ ] have not been transmitted as
  i. [ ] applicant chose not to make amendments under PCT Article 19.
  Date of mailing of Search Report (from form PCT/ISA/210): __________.
  ii. [ ] the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.

6. [ ] A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. 371(c)(3)):
  a. [ ] is transmitted herewith.
  b. [ ] is not required as the amendments were made in the English language.
  c. [ ] has not been transmitted for reasons indicated at point 5(c) above.

7. [x] A copy of the international examination report (PCT/IPEA/409)
  [x] is transmitted herewith.
  [ ] is not required as the application was filed with the United States Receiving Office.

8. [ ] Annex(es) to the international preliminary examination report
  a. [ ] is/are transmitted herewith.
  b. [ ] is/are not required as the application was filed with the United States Receiving Office.

9. [ ] A translation of the annexes to the international preliminary examination report
  a. [ ] is transmitted herewith.
  b. [ ] is not required as the annexes are in the English language.

10. [X] An oath or declaration of the inventor (35 U.S.C. 371(c)(4)) complying with 35 U.S.C. 115
  a. [ ] was previously submitted by applicant on ____________.
  Date
  b. [x] is submitted herewith, and such oath or declaration
    i. [x] is attached to the application.
    ii. [ ] identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. 1.70.

iii. [ ] will follow.

Other document(s) or information included:

11. [x] An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):
   a. [ x ] is transmitted herewith.
   b. [ ] has been transmitted by the International Bureau. Date of mailing (from form PCT/IB/308): ________________.
   c. [ ] is not required, as the application was searched by the United States International Searching Authority.
   d. [ ] will be transmitted promptly upon request.
   e. [ ] has been submitted by applicant on ________________ (Date).

12. [X] An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98:
   a. [X] is transmitted herewith.
      Also transmitted herewith is/are:
      [X] Form PTO-1449 (PTO/SB/08A and 08B).
      [X] Copies of citations listed.
   b. [ ] will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. 371(c).
   c. [ ] was previously submitted by applicant on ________________ (Date).

13. [x ] An assignment document is transmitted herewith for recording.

A separate [x ] "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or[ ] FORM PTO 1595 is also attached.

________________________________________
________________________________________
________________________________________

14. [X] Additional documents:
   a. [ ] Copy of request (PCT/RO/101)
   b. [x ] International Publication No. WO01/19654
      i. [ ] Specification, claims and drawing
      ii. [ x ] Front page only
   c. [X] Preliminary amendment (37 C.F.R. § 1.121)
   d. [ ] Other

________________________________________
________________________________________
________________________________________

15. [X] The above checked items are being transmitted

a. [X] before 30 months from any claimed priority date.
b. [ ] after 30 months.

16. [ ] Certain requirements under 35 U.S.C. 371 were previously submitted by the applicant on ____________, namely:

______________________________________________
______________________________________________
______________________________________________

## AUTHORIZATION TO CHARGE ADDITIONAL FEES

***WARNING:*** *Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges if extra claims are authorized.*

*NOTE:* *"A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).*

*NOTE:* *"Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).*

[X] The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the entire pendency of this application to Account No. 18-0013.

[X] 37 C.F.R. 1.492(a)(1), (2), (3), and (4) (filing fees)

***WARNING:*** *Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.*

[X] 37 C.F.R. 1.492(b), (c) and (d) (presentation of extra claims)

*NOTE:* *Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.*

[X] 37 C.F.R. 1.17 (application processing fees)
[X] 37 C.F.R. 1.17(a)(1)-(5)(extension fees pursuant to § 1.136(a).
[ ] 37 C.F.R. 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. 1.311(b))

*NOTE:* *Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of*

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*allowance. 37 C.F.R. § 1.311(b).*

*NOTE: 37 C.F.R. 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.*

[X] 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

**SIGNATURE OF PRACTITIONER**

Reg. No.: 33,373

Joseph V. Coppola, Sr.
*(type or print name of practitioner)*

Tel. No.: (248) 594-0650

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PATENT TRADEMARK OFFICE

Express Mail EV051019227US

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# APPLICATION DATA SHEET (AP9714)

## INVENTOR INFORMATION


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## CORRESPONDENCE INFORMATION

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| Telephone:: | (248) 594-0600 |
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## APPLICATION INFORMATION

| | |
|---|---|
| Title Line One: | Method for Detecting and Evaluating the |
| Title Line Two: | Conditions of Vehicle Movement Dynamics for |
| Title Line Three: | a Motor Vehicle |
| Total Drawings Sheets: | 2 |
| Formal Drawings?: | yes |
| Application Type: | Utility |
| Docket Number:: | AP9714 |
| Secrecy Order in Parent Appl.?:: | No |

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**REPRESENTATIVE INFORMATION**

Representative Customer Number:: 010291

**CONTINUITY INFORMATION**

This application was filed on 14/Sept/2000 as PCT International Application No. PCT/EP00/08989 and claims priority under 35 USC §119(a)-(d) or §365(b) to German Application No. 19944098.0 filed 15/Sept/1999 and German Application No. 10026111.6 filed 26/May/2000 and German Application No. 10044291.9 filed 7/Sept/2000.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Bleckmann et al.

Int'l Application No.: PCT/EP00/08989

Int'l Filing Date: 14 September 2000

Serial No.: Group Art Unit:

Filed: Herewith Examiner:

For: Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

Attorney Docket No.: P9714 Paper No.

Box PCT
Commissioner of Patents
Washington, D.C. 20231
Attn: EO/US

CERTIFICATE OF MAILING/TRANSMISSION (37 CFR 1.8(a))

I hereby certify that this correspondence is, on the date shown below, being:

☑ deposited with the United States Postal Service with sufficient postage as Express Mail, Post Office to Addressee, Mailing Label No.: EV051019227US addressed to Box PCT, Commissioner for Patents, Washington, DC 20231

☐ transmitted by facsimile to the Patent and Trademark Office. to Examiner ____________ at ____________

Date: 3/15/02

Joyce Krumpe
Signature

Joyce Krumpe

## PRELIMINARY AMENDMENT

Dear Sir:

Please amend the application as follows prior to examination on the merits.

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## IN THE DRAWINGS

Figure 1a,b has been amended as indicated in red on the marked up sheet included with this Preliminary Amendment. Please enter these proposed drawing changes into the official record of the application.

## IN THE CLAIMS

Please cancel claims 1-13 and add the following new claims.

14. (New) Method for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of a wheel force sensor, which operates across a preadjusted air slot and senses a rotating encoder attached to the vehicle tire or wheel, comprising the steps of:

a) operating the sensor under known conditions that result in minimal lateral forces exerted upon the rotating encoder,

b) measuring a signal generated by the sensor under the conditions of step a) and using that signal as a reference valve by which to determine the presence of a transverse force on the wheel.

15. (New) Method as claimed in claim 14, wherein the signal is standardized to at least one nominal value when the driving behavior is stationary.

16. (New) Method as claimed in claim 14, wherein the signal is a sinusoidal alternating voltage or alternating current signal, and the nominal value is determined with each peak value of the half wave (amplitude) or with each alternation of a pole or marking of the encoder.

17. (New) Method as claimed in claim 15, wherein a value is associated with the nominal value which reproduces a zero point (offset) of the transverse force acting on the wheel or the tire.

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18. (New) Method as claimed in claim 17, wherein the transverse forces are determined in dependence on the amplitude variations according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude.

19. (New) Method as claimed in claim 18, wherein the amplitude variations are attributed by means of the inverse function to changes in distance according to the relation

$$Dis_{usefuleffect} = k * \ln\left(\frac{Amp}{Amp_{no\min alvalue}}\right)$$

wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant.

20. (New) Method as claimed in claim 18, wherein the transverse forces are basically determined as a function of the changes in distance.

21. (New) Method as claimed in claim 16, wherein the nominal value is maintained until the predetermined driving behavior is detected.

22. (New) Control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, which take the preadjusted air gap between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire, comprising:

a determination unit which sets an operating point of the output signal of the pick-up irrespective of the air gap.

23. (New) Control circuit as claimed in claim 22, comprising a standardization of the output signal to at least one nominal value when the vehicle movement behavior is stationary.

24.(New) Control circuit as claimed in claim 23, wherein the output signal of the pick-up for measuring data or the signal-evaluating device is a sinusoidal alternating voltage or alternating current signal, and the determination unit determines the nominal value with each peak value of the half wave (amplitude) or with each alternation of the poles or markings of the encoder.

25. (New) Control circuit as claimed in claim 24, further comprising means attributing a value to the nominal value which represents the zero point (offset) of the transverse force, and in that the determination unit determines transverse forces in dependence on the amplitude variations according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude.

26. (New) Control circuit as claimed in claim 25, wherein the determination unit attributes the amplitude variations by means of an inverse function to changes in distance according to the relation

$$Dis_{usefuleffect} = k * \ln\left(\frac{Amp}{Amp_{no\min alvalue}}\right)$$

wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant.

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## REMARKS

Prior to a formal examination of the above-identified application, acceptance of the new claims and the enclosed substitute specification (under 37 CFR 1.125) is respectfully requested. It is believed that the substitute specification and new claims will facilitate processing of the application in accordance with M.P.E.P. 608.01(q). The substitute specification and new claims are in compliance with 37 CFR 1.52 (a and b) and, while making no substantive changes, are submitted to conform this case to the formal requirements and long-established formal standards of U.S. Patent Office practice, and to provide improved idiom and better grammatical form.

The enclosed substitute specification is presented herein in both marked-up and clean versions.

## STATEMENT

The undersigned, an attorney registered to practice before the office, hereby states that the enclosed substitute specification includes the same changes as are indicated in the mark-up copy of the original specification. The substitute specification contains no new subject matter.

Respectfully submitted,

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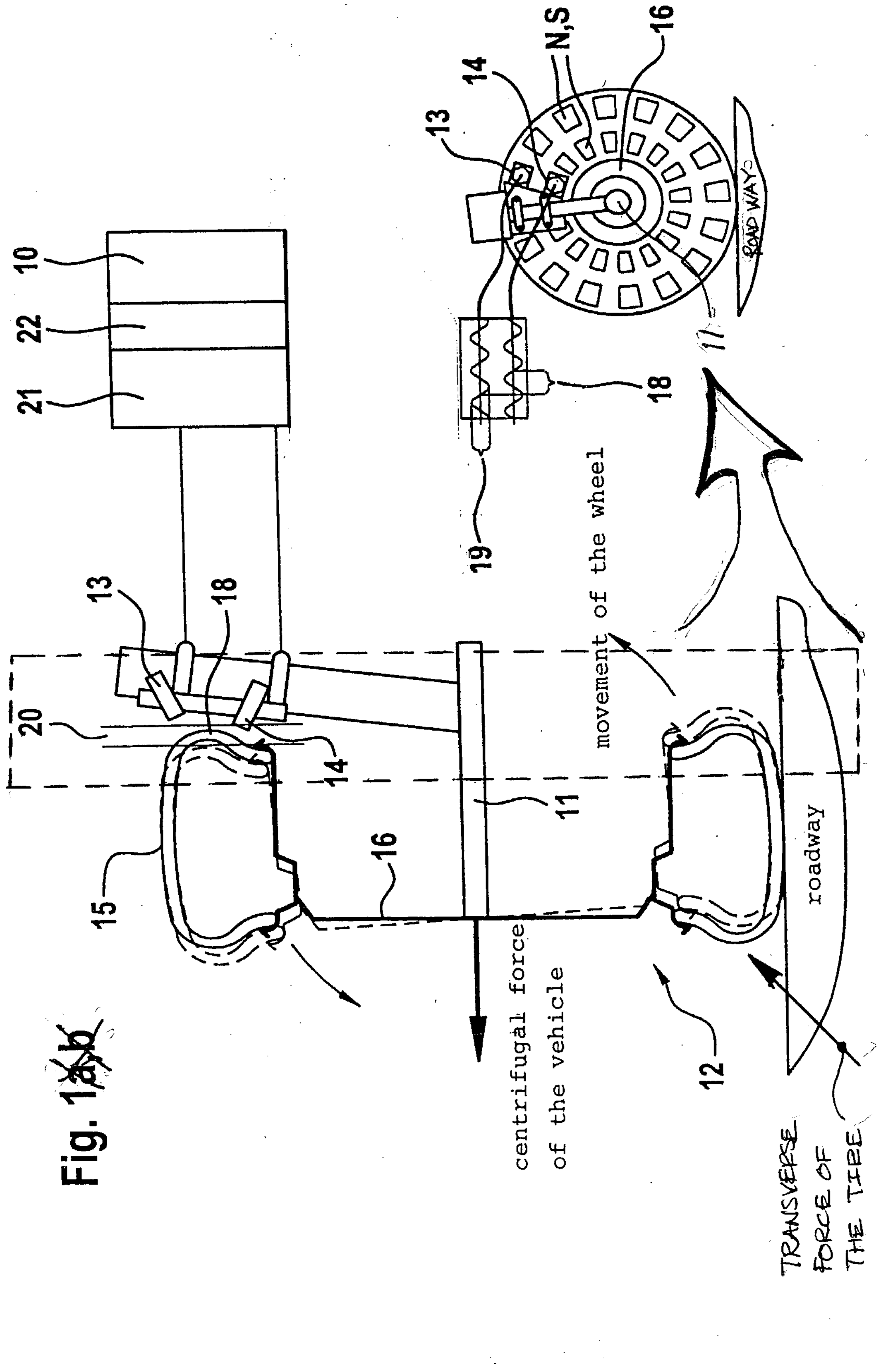
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movement of the wheel
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of the vehicle
roadway
TRANSVERSE
FORCE OF
THE TIRE

Fig. 1a

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SUBSTITUTE SPECIFICATION: MARKED UP COPY

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[PC 9714]

# Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

## TECHNICAL FIELD

The present invention generally relates to electronic sensors and more particularly relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors[, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire].

## BACKGROUND OF THE INVENTION

Many methods for controlling the driving behavior of a vehicle are known in the art which use tire sensors for sensing the forces and moments that act on the tires. The term 'tire sensor (SWT sensor)' in this context refers to the encoder mounted in or on the tire and at least one pick-up for measuring data that is associated with the encoder and mounted on the chassis in a stationary manner. Whereas in EP 0 444 109 B1 the deformation of the tire profile area of the tire, i.e., the tire print, is monitored, WO 96/10505 proposes detecting the deformation of the side wall of a tire, i.e., torsion deformations, by measuring a period of time that elapses between the passing of at least two markings arranged on the rotating wheel at a different radius relative to the axis of

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rotation. WO 97/44673 describes a tire sensor which detects a variation of the phase position and/or the amplitude between output signals sent by pick-ups for measuring data when the tire is deformed due to forces acting on the tire. The size of the air slot between the encoder or the magnetic areas embedded into the tire side wall and the e.g. active, magnetoresistive pick-ups for measuring data produce the signal which is used for the allocation of the lateral or transverse forces that act upon the tire. Consequently, the variations of the signals established by the pick-up for measuring data reproduce the deformations or variations of the tire side wall which are caused by the transverse forces that act on the wheels, while the change in the phase position between the two pick-ups for measuring data which are arranged on an outside and an inside radius relative to the axis of rotation of the wheel define a signal for the calculation of the longitudinal forces.

Another air tire equipped with a magnetic encoder is described in DE 196 20 582 A1 to which reference is made in full extent. The forces that act on a wheel having a tire of this type are reproduced in the way of signals correlated to forces in the pick-ups for measuring data or signal conditioning devices and used in motor vehicle control systems to regulate or control vehicles, especially for proportioning and/or modulating the brake pressure in the wheel brakes of the wheels.

When determining the functional correlation between the amplitude and/or phase signal and the forces that act on the wheels or the tires, measuring wheel rims are used as described, for example, in EP 0 352 788 A2. It is necessary in this context to arrange the pick-ups on the vehicle body or

the wheel suspension so as to duplicate them in order to make the signals reproducible that are responsive to the air slot. Tolerances which occur in the arrangement or manufacture of the pick-ups for measuring data, and/or different wheel rim systems, e.g. with different rim offsets, cause discrepancies in determining the forces that act on the wheels or tires.

## BRIEF SUMMARY OF THE INVENTION

An object of the present invention is to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors.

[According to the present invention, this object is achieved by the features of the independent claims. Dependent claims are directed to preferred embodiments.]

Advantageously, the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data can be taken into account as a standard of the transverse forces that act on the wheel or the tire in order to detect and evaluate driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably tire sensors. The fact that, according to the present invention, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device connected downstream of the pick-up for measuring data is set irrespective of the preadjustment of the said point, permits processing the output signal in an error-minimized fashion without impairing the signal quality, because the said signal is determined irrespective of the above preadjusted distance

between the pick-up for measuring data and the encoder. Wheel rims with a different rim offset, yet with the same amount of rigidity, may be used. In addition, the distance of the pick-up for measuring data may be varied as desired by way of the area of resolution, without the need for adaptions of the functional representation between the amplitude and the transverse force.

Favorably, a generic control circuit is so configured that it comprises a determination unit which adjusts the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device irrespective of the point's preadjustment, for detecting and evaluating driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably by tire sensors, that take into account the preadjusted air slot between at least one rotating encoder or at least one pick-up for measuring data as a standard of the transverse forces acting on the wheel or on the tire.

According to the present invention, the method and the control circuit are so designed that the output signal is adapted to the vehicle-related distances between the pick-up for measuring data and the encoder. The features of a suitable method and a control circuit include that the output signal is standardized to at least one nominal value in the event of a stationary driving behavior free from longitudinal or transverse forces. The stationary driving behavior which is free from longitudinal or transverse forces is determined by means of input quantities which are furnished by conventional sensors and comprise at least the transverse acceleration, the longitudinal acceleration, and the steering angle velocity.

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Suitably, low longitudinal or transverse forces, or almost no such forces, act on the wheel or the tire at that moment. The following conditions, either individually or in any combination desired, can be made the basis of a stationary driving behavior which is free from longitudinal and transverse forces:

$|\text{transverse acceleration}| < 0.07g$

$|\text{longitudinal acceleration}| < 0.1g$

$|\text{steering angle}| < 1°$

$|\text{steering angle velocity}| < 20$ [degree/s]

forward driving

gearshift-dependent speed

| | | |
|---|---|---|
| first gear | <10 | km/h |
| second gear | <30 | km/h |
| third gear | <50 | km/h |
| fourth gear | <100 | km/h |
| fifth gear | <150 | km/h |

When, preferably, all these conditions are stable for a period of time of roughly 70 msec, that value (nominal value) will be defined to which the output signal may be related (standardized).

The output signal furnished by the pick-up for measuring data or a signal-conditioning device is a sinusoidal alternating voltage or alternating current signal, whose nominal value is determined with each peak value of the half wave (amplitude) or with each change of the poles or markings of the encoder when the conditions of the stationary driving behavior are satisfied. Associated with the nominal value is a value which

represents the zero point (offset) of the transverse force acting on the wheel and/or the tire.

The transverse forces are then determined during dynamic conditions of the vehicle in dependence on the amplitude variations according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = \mathrm{k} * \ln\left(\frac{Amp}{Amp_{nom.\ value}}\right) = \mathrm{k} * (\ln(Amp) - \ln(Amp_{nom.value})) = \mathrm{k} * \ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $\mathrm{Dis}_{\text{useful effect}}$ = changes in distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

The transverse forces may then be determined basically as a function of the changes in distance.

An embodiment of the present invention will be explained in detail in the following by making reference to the accompanying drawings.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

[In the drawings,]

Figure 1[a,b] is a schematic view of a control circuit for detecting and evaluating the deformations of the wheel when the wheel is subjected to transverse or lateral forces.

Figure 2 shows a characteristic curve of the pick-up for measuring data of a tire sensor.

Figure 3 shows the characteristic curve according to Figure 2, with direct voltage and signs being removed.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Figure[s 1 a and b show] 1 shows a control circuit 10 which is connected to two magnetic-field-sensitive pick-ups for measuring data 13, 14 that are mounted on the chassis of a motor vehicle spaced radially from an axis of rotation 11 of wheel 12. The control circuit may be a component part of the pick-ups for measuring data or a separate unit or component of an ABS (anti-lock control system), TCS (traction slip control system), ESP (electronic driving stability control system), EHB (electrohydraulic brake control system), a vehicle suspension control system, and/or an EMB (electromechanic brake) control system. Vehicle tire 15 includes an encoder 17 with permanent-magnetic areas of alternating polarity N, S. The permanent-magnetic areas N, S are embedded in tire wall 17 of wheel 12.

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A distance (air slot 20) is preadjusted between the encoder 18 and the pick-ups for measuring data 13, 14. When the wheel is deformed (= wheel rim 16 with tire 15) due to the longitudinal forces acting on the tire, the pick-ups for measuring data 13, 14 detect a variation of the phase position 18 which occurs between the test signals output by the pick-ups for measuring data 13, 14.

Further, at least one pick-up for measuring data 13 detects a change of the amplitude 19 of the test signal when the wheel 12 is deformed due to transverse forces acting on the tire 15. The test signal is amplified by an electronic circuit integrated in the sensor and converted into an output signal. The operating point of the output signal of the pick-up for measuring data 13 that is responsive to the air slot 20 is adjusted in a determination unit 21 irrespective of the preadjustment. When the vehicle exhibits a stationary driving behavior, the output signal is standardized to a nominal value, and the nominal value is correlated to the zero point of the transverse force by way of means 21. Subsequently, there is a reproducible correlation between the variation of the amplitude signal and the variation of the transverse force.

The sinusoidal output signal which is produced by the effect of the encoder 17 at the magnetic-field-sensitive pick-up for measuring data 13 and the peak value of which varies with the air slot 20 may be an alternating voltage signal or an alternating current signal. The alternating current signal can be transformed into an alternating voltage signal in a signal-conditioning device associated with the pick-up for measuring data 13. Figures 2 and 3 [and 4] show the correlation between the air slot 20 and the amplitude signal of the pick-up for

measuring data 13, namely in a non-linear, almost exponential, form. The voltage of the output signal (sensor voltage) is plotted against the air slot 20 in Figure 2[, while]. In Figure 3, the same output signal is shown (as that of Figure 2) except that [the output signal, cleared from direct voltage and signs, is plotted against the air slot in Figure 3] the fixed voltage offset is removed and the negative portion of the signal is absent.

The operation of the method of the present invention is as follows:

After the start of the motor vehicle, the driving behavior is determined with signals of conventional sensors, such as transverse acceleration and longitudinal acceleration sensors, yaw rate sensors, steering angle sensors and like elements, because the adaption of the amplitude signal to the air slot 20 shall take place under stationary conditions only. To detect a stationary driving behavior free from longitudinal and/or transverse forces, it is preferred that the following conditions are satisfied:

|transverse acceleration|< 0.07g

|longitudinal acceleration|< 0.1g

|steering angle|< 1°

|steering angle velocity| < 20[degree/s]

forward driving

gearshift-dependent speed

first gear <10 km/h
second gear <30 km/h
third gear <50 km/h
fourth gear <100 km/h
fifth gear <150 km/h.

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When these conditions are satisfied and remain stable for roughly 70 msec, a stationary driving behavior free from longitudinal or transverse forces prevails. The amplitude signal is then standardized to a nominal value with each peak value of the half wave or with each alternation of the magnetic areas N, S or poles or markings of the encoder 17. This nominal value is correlated with a zero point of the transverse force or force offset which was determined one time almost synchronously by a force measuring element, preferably a measuring wheel rim, under the influence of the forces that occur on wheel 12. The value of the transverse force is ideally 0 Newton when the driving behavior is stationary.

Starting from the standardized nominal value of the amplitude signal, which value is correlated with the force offset, the transverse forces during dynamic conditions of the vehicle are determined in dependence on the amplitude variations $Amp_{usefuleffect}$ according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{useful\ effect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = \mathrm{k} * \ln\left(\frac{Amp}{Amp_{nom.\ value}}\right) = \mathrm{k} * (\ln(Amp) - \ln(Amp_{nom.value})) = \mathrm{k} * \ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

The transverse forces may then be determined basically as a function of the changes in distance.

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[Abstract:]

**Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle**

## ABSTRACT OF THE DISCLOSURE

The present invention relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire. In order to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device is set irrespective of the preadjustment of the said point which was made during predetermined driving behavior.

[(Figure 3)]

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# Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

## TECHNICAL FIELD

**[0001]** The present invention generally relates to electronic sensors and more particularly relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors.

## BACKGROUND OF THE INVENTION

**[0002]** Many methods for controlling the driving behavior of a vehicle are known in the art which use tire sensors for sensing the forces and moments that act on the tires. The term 'tire sensor (SWT sensor)' in this context refers to the encoder mounted in or on the tire and at least one pick-up for measuring data that is associated with the encoder and mounted on the chassis in a stationary manner. Whereas in EP 0 444 109 B1 the deformation of the tire profile area of the tire, i.e., the tire print, is monitored, WO 96/10505 proposes detecting the deformation of the side wall of a tire, i.e., torsion deformations, by measuring a period of time that elapses between the passing of at least two markings arranged on the rotating wheel at a different radius relative to the axis of rotation. WO 97/44673 describes a tire sensor which detects a variation of the phase position and/or the amplitude between output signals sent by pick-ups for measuring data when the tire is deformed due to forces acting on the tire. The size of the air slot between the encoder or the magnetic areas embedded into the tire side wall and the e.g. active,

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magnetoresistive pick-ups for measuring data produce the signal which is used for the allocation of the lateral or transverse forces that act upon the tire. Consequently, the variations of the signals established by the pick-up for measuring data reproduce the deformations or variations of the tire side wall which are caused by the transverse forces that act on the wheels, while the change in the phase position between the two pick-ups for measuring data which are arranged on an outside and an inside radius relative to the axis of rotation of the wheel define a signal for the calculation of the longitudinal forces.

**[0003]** Another air tire equipped with a magnetic encoder is described in DE 196 20 582 A1 to which reference is made in full extent. The forces that act on a wheel having a tire of this type are reproduced in the way of signals correlated to forces in the pick-ups for measuring data or signal conditioning devices and used in motor vehicle control systems to regulate or control vehicles, especially for proportioning and/or modulating the brake pressure in the wheel brakes of the wheels.

**[0004]** When determining the functional correlation between the amplitude and/or phase signal and the forces that act on the wheels or the tires, measuring wheel rims are used as described, for example, in EP 0 352 788 A2. It is necessary in this context to arrange the pick-ups on the vehicle body or the wheel suspension so as to duplicate them in order to make the signals reproducible that are responsive to the air slot. Tolerances which occur in the arrangement or manufacture of the pick-ups for measuring data, and/or different wheel rim

systems, e.g. with different rim offsets, cause discrepancies in determining the forces that act on the wheels or tires.

## BRIEF SUMMARY OF THE INVENTION

**[0005]** An object of the present invention is to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors.

**[0006]** Advantageously, the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data can be taken into account as a standard of the transverse forces that act on the wheel or the tire in order to detect and evaluate driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably tire sensors. The fact that, according to the present invention, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device connected downstream of the pick-up for measuring data is set irrespective of the preadjustment of the said point, permits processing the output signal in an error-minimized fashion without impairing the signal quality, because the said signal is determined irrespective of the above preadjusted distance between the pick-up for measuring data and the encoder. Wheel rims with a different rim offset, yet with the same amount of rigidity, may be used. In addition, the distance of the pick-up for measuring data may be varied as desired by way of the area of resolution, without the need for adaptions of the functional representation between the amplitude and the transverse force.

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**[0007]** Favorably, a generic control circuit is so configured that it comprises a determination unit which adjusts the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device irrespective of the point's preadjustment, for detecting and evaluating driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably by tire sensors, that take into account the preadjusted air slot between at least one rotating encoder or at least one pick-up for measuring data as a standard of the transverse forces acting on the wheel or on the tire.

**[0008]** According to the present invention, the method and the control circuit are so designed that the output signal is adapted to the vehicle-related distances between the pick-up for measuring data and the encoder. The features of a suitable method and a control circuit include that the output signal is standardized to at least one nominal value in the event of a stationary driving behavior free from longitudinal or transverse forces. The stationary driving behavior which is free from longitudinal or transverse forces is determined by means of input quantities which are furnished by conventional sensors and comprise at least the transverse acceleration, the longitudinal acceleration, and the steering angle velocity. Suitably, low longitudinal or transverse forces, or almost no such forces, act on the wheel or the tire at that moment. The following conditions, either individually or in any combination desired, can be made the basis of a stationary driving behavior which is free from longitudinal and transverse forces:

$|\text{transverse acceleration}| < 0.07g$

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|longitudinal acceleration|< 0.1g

|steering angle|< 1°

|steering angle velocity|< 20 [degree/s]

forward driving

gearshift-dependent speed

| | | |
|---|---|---|
| first gear | <10 | km/h |
| second gear | <30 | km/h |
| third gear | <50 | km/h |
| fourth gear | <100 | km/h |
| fifth gear | <150 | km/h |

**[0009]** When, preferably, all these conditions are stable for a period of time of roughly 70 msec, that value (nominal value) will be defined to which the output signal may be related (standardized).

**[0010]** The output signal furnished by the pick-up for measuring data or a signal-conditioning device is a sinusoidal alternating voltage or alternating current signal, whose nominal value is determined with each peak value of the half wave (amplitude) or with each change of the poles or markings of the encoder when the conditions of the stationary driving behavior are satisfied. Associated with the nominal value is a value which represents the zero point (offset) of the transverse force acting on the wheel and/or the tire.

**[0011]** The transverse forces are then determined during dynamic conditions of the vehicle in dependence on the amplitude variations according to the relation

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$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = \mathrm{k} * \ln\left(\frac{Amp}{Amp_{nom.\ value}}\right) = \mathrm{k} * (\ln(Amp) - \ln(Amp_{nom.value})) = \mathrm{k} * \ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

**[0012]** The transverse forces may then be determined basically as a function of the changes in distance.

**[0013]** An embodiment of the present invention will be explained in detail in the following by making reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]** Figure 1 is a schematic view of a control circuit for detecting and evaluating the deformations of the wheel when the wheel is subjected to transverse or lateral forces.

**[0015]** Figure 2 shows a characteristic curve of the pick-up for measuring data of a tire sensor.

**[0016]** Figure 3 shows the characteristic curve according to Figure 2, with direct voltage and signs being removed.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0017]** Figure 1 shows a control circuit 10 which is connected to two magnetic-field-sensitive pick-ups for measuring data 13, 14 that are mounted on the chassis of a motor vehicle spaced radially from an axis of rotation 11 of wheel 12. The control circuit may be a component part of the pick-ups for measuring data or a separate unit or component of an ABS (anti-lock control system), TCS (traction slip control system), ESP (electronic driving stability control system), EHB (electrohydraulic brake control system), a vehicle suspension control system, and/or an EMB (electromechanic brake) control system. Vehicle tire 15 includes an encoder 17 with permanent-magnetic areas of alternating polarity N, S. The permanent-magnetic areas N, S are embedded in tire wall 17 of wheel 12.

**[0018]** A distance (air slot 20) is preadjusted between the encoder 18 and the pick-ups for measuring data 13, 14. When the wheel is deformed (= wheel rim 16 with tire 15) due to the longitudinal forces acting on the tire, the pick-ups for measuring data 13, 14 detect a variation of the phase position 18 which occurs between the test signals output by the pick-ups for measuring data 13, 14.

**[0019]** Further, at least one pick-up for measuring data 13 detects a change of the amplitude 19 of the test signal when the wheel 12 is deformed due to transverse forces acting on

the tire 15. The test signal is amplified by an electronic circuit integrated in the sensor and converted into an output signal. The operating point of the output signal of the pick-up for measuring data 13 that is responsive to the air slot 20 is adjusted in a determination unit 21 irrespective of the preadjustment. When the vehicle exhibits a stationary driving behavior, the output signal is standardized to a nominal value, and the nominal value is correlated to the zero point of the transverse force by way of means 21. Subsequently, there is a reproducible correlation between the variation of the amplitude signal and the variation of the transverse force.

**[0020]** The sinusoidal output signal which is produced by the effect of the encoder 17 at the magnetic-field-sensitive pick-up for measuring data 13 and the peak value of which varies with the air slot 20 may be an alternating voltage signal or an alternating current signal. The alternating current signal can be transformed into an alternating voltage signal in a signal-conditioning device associated with the pick-up for measuring data 13. Figures 2 and 3 show the correlation between the air slot 20 and the amplitude signal of the pick-up for measuring data 13, namely in a non-linear, almost exponential, form. The voltage of the output signal (sensor voltage) is plotted against the air slot 20 in Figure 2. In Figure 3, the same output signal is shown (as that of Figure 2) except that the fixed voltage offset is removed and the negative portion of the signal is absent.

**[0021]** The operation of the method of the present invention is as follows:

After the start of the motor vehicle, the driving behavior is determined with signals of conventional sensors, such as

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transverse acceleration and longitudinal acceleration sensors, yaw rate sensors, steering angle sensors and like elements, because the adaption of the amplitude signal to the air slot 20 shall take place under stationary conditions only. To detect a stationary driving behavior free from longitudinal and/or transverse forces, it is preferred that the following conditions are satisfied:

$|\text{transverse acceleration}| < 0.07g$

$|\text{longitudinal acceleration}| < 0.1g$

$|\text{steering angle}| < 1°$

$|\text{steering angle velocity}| < 20[\text{degree/s}]$

forward driving

gearshift-dependent speed

| | | |
|---|---|---|
| first gear | <10 | km/h |
| second gear | <30 | km/h |
| third gear | <50 | km/h |
| fourth gear | <100 | km/h |
| fifth gear | <150 | km/h. |

**[0022]** When these conditions are satisfied and remain stable for roughly 70 msec, a stationary driving behavior free from longitudinal or transverse forces prevails. The amplitude signal is then standardized to a nominal value with each peak value of the half wave or with each alternation of the magnetic areas N, S or poles or markings of the encoder 17. This nominal value is correlated with a zero point of the transverse force or force offset which was determined one time almost synchronously by a force measuring element, preferably a measuring wheel rim, under the influence of the forces that occur on wheel 12. The value of the transverse force is ideally 0 Newton when the driving behavior is stationary.

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[0023] Starting from the standardized nominal value of the amplitude signal, which value is correlated with the force offset, the transverse forces during dynamic conditions of the vehicle are determined in dependence on the amplitude variations $Amp_{usefuleffect}$ according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{useful\ effect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = \mathrm{k} * \ln\left(\frac{Amp}{Amp_{nom.\ value}}\right) = \mathrm{k} * (\ln(Amp) - \ln(Amp_{nom.value})) = \mathrm{k} * \ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $\mathrm{Dis}_{useful\ effect}$ = changes in distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

[0024] The transverse forces may then be determined basically as a function of the changes in distance.

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# Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

## ABSTRACT OF THE DISCLOSURE

**[0025]** The present invention relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire. In order to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device is set irrespective of the preadjustment of the said point which was made during predetermined driving behavior.

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# Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

The present invention relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire.

Many methods for controlling the driving behavior of a vehicle are known in the art which use tire sensors for sensing the forces and moments that act on the tires. The term 'tire sensor (SWT sensor)' in this context refers to the encoder mounted in or on the tire and at least one pick-up for measuring data that is associated with the encoder and mounted on the chassis in a stationary manner. Whereas in EP 0 444 109 B1 the deformation of the tire profile area of the tire, i.e., the tire print, is monitored, WO 96/10505 proposes detecting the deformation of the side wall of a tire, i.e., torsion deformations, by measuring a period of time that elapses between the passing of at least two markings arranged on the rotating wheel at a different radius relative to the axis of rotation. WO 97/44673 describes a tire sensor which detects a variation of the phase position and/or the amplitude between output signals sent by pick-ups for measuring data when the tire is deformed due to forces acting on the tire. The size of the air slot between the encoder or the magnetic areas embedded into the tire side wall and the e.g. active, magnetoresistive pick-ups for measuring data produce the signal which is used for the allocation of the lateral or transverse forces that act upon the tire. Consequently, the variations of the signals established by the

pick-up for measuring data reproduce the deformations or variations of the tire side wall which are caused by the transverse forces that act on the wheels, while the change in the phase position between the two pick-ups for measuring data which are arranged on an outside and an inside radius relative to the axis of rotation of the wheel define a signal for the calculation of the longitudinal forces.

Another air tire equipped with a magnetic encoder is described in DE 196 20 582 A1 to which reference is made in full extent. The forces that act on a wheel having a tire of this type are reproduced in the way of signals correlated to forces in the pick-ups for measuring data or signal conditioning devices and used in motor vehicle control systems to regulate or control vehicles, especially for proportioning and/or modulating the brake pressure in the wheel brakes of the wheels.

When determining the functional correlation between the amplitude and/or phase signal and the forces that act on the wheels or the tires, measuring wheel rims are used as described, for example, in EP 0 352 788 A2. It is necessary in this context to arrange the pick-ups on the vehicle body or the wheel suspension so as to duplicate them in order to make the signals reproducible that are responsive to the air slot. Tolerances which occur in the arrangement or manufacture of the pick-ups for measuring data, and/or different wheel rim systems, e.g. with different rim offsets, cause discrepancies in determining the forces that act on the wheels or tires.

An object of the present invention is to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors.

According to the present invention, this object is achieved by the features of the independent claims. Dependent claims are directed to preferred embodiments.

Advantageously, the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data can be taken into account as a standard of the transverse forces that act on the wheel or the tire in order to detect and evaluate driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably tire sensors. The fact that, according to the present invention, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device connected downstream of the pick-up for measuring data is set irrespective of the preadjustment of the said point, permits processing the output signal in an error-minimized fashion without impairing the signal quality, because the said signal is determined irrespective of the above preadjusted distance between the pick-up for measuring data and the encoder. Wheel rims with a different rim offset, yet with the same amount of rigidity, may be used. In addition, the distance of the pick-up for measuring data may be varied as desired by way of the area of resolution, without the need for adaptions of the functional representation between the amplitude and the transverse force.

Favorably, a generic control circuit is so configured that it comprises a determination unit which adjusts the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device irrespective of the point's preadjustment, for detecting and evaluating driving-dynamics conditions of a motor vehicle by means of wheel force sensors, preferably by tire sensors, that take into account the preadjusted air slot between at least one rotating encoder or at least one pick-up for measuring data as a

standard of the transverse forces acting on the wheel or on the tire.

According to the present invention, the method and the control circuit are so designed that the output signal is adapted to the vehicle-related distances between the pick-up for measuring data and the encoder. The features of a suitable method and a control circuit include that the output signal is standardized to at least one nominal value in the event of a stationary driving behavior free from longitudinal or transverse forces. The stationary driving behavior which is free from longitudinal or transverse forces is determined by means of input quantities which are furnished by conventional sensors and comprise at least the transverse acceleration, the longitudinal acceleration, and the steering angle velocity. Suitably, low longitudinal or transverse forces, or almost no such forces, act on the wheel or the tire at that moment. The following conditions, either individually or in any combination desired, can be made the basis of a stationary driving behavior which is free from longitudinal and transverse forces:

|transverse acceleration|< 0.07g

|longitudinal acceleration|< 0.1g

|steering angle|< 1°

|steering angle velocity|< 20[degree/s]

forward driving

gearshift-dependent speed

| | | |
|---|---|---|
| first gear | <10 | km/h |
| second gear | <30 | km/h |
| third gear | <50 | km/h |
| fourth gear | <100 | km/h |
| fifth gear | <150 | km/h |

When, preferably, all these conditions are stable for a period of time of roughly 70 msec, that value (nominal value) will be defined to which the output signal may be related (standardized).

The output signal furnished by the pick-up for measuring data or a signal-conditioning device is a sinusoidal alternating voltage or alternating current signal, whose nominal value is determined with each peak value of the half wave (amplitude) or with each change of the poles or markings of the encoder when the conditions of the stationary driving behavior are satisfied. Associated with the nominal value is a value which represents the zero point (offset) of the transverse force acting on the wheel and/or the tire.

The transverse forces are then determined during dynamic conditions of the vehicle in dependence on the amplitude variations according to the relation

$$Amp_{usefulefffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = k*\ln\left(\frac{Amp}{Amp_{nom.\,value}}\right) = k*(\ln(Amp) - \ln(Amp_{nom.value})) = k*\ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $\mathrm{Dis}_{useful\ effect}$ = changes in

distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

The transverse forces may then be determined basically as a function of the changes in distance.

An embodiment of the present invention will be explained in detail in the following by making reference to the accompanying drawings.

In the drawings,

Figure 1a,b is a view of a control circuit for detecting and evaluating the deformations of the wheel when subjected to transverse or lateral forces.

Figure 2 shows a characteristic curve of the pick-up for measuring data of a tire sensor.

Figure 3 shows the characteristic curve according to Figure 2, with direct voltage and signs being removed.

Figures 1 a and b show a control circuit 10 which is connected to two magnetic-field-sensitive pick-ups for measuring data 13, 14 that are mounted on the chassis of a motor vehicle spaced radially from an axis of rotation 11 of wheel 12. The control circuit may be a component part of the pick-ups for measuring data or a separate unit or component of an ABS (anti-lock control system), TCS (traction slip control system), ESP (electronic driving stability control system), EHB (electrohydraulic brake control system), a vehicle suspension control system, and/or an EMB (electromechanic brake) control system. Vehicle tire 15 includes an encoder 17 with permanent-magnetic areas of alternating polarity N, S. The permanent-

magnetic areas N, S are embedded in tire wall 17 of wheel 12. A distance (air slot 20) is preadjusted between the encoder 18 and the pick-ups for measuring data 13, 14. When the wheel is deformed (= wheel rim 16 with tire 15) due to the longitudinal forces acting on the tire, the pick-ups for measuring data 13, 14 detect a variation of the phase position 18 which occurs between the test signals output by the pick-ups for measuring data 13, 14. Further, at least one pick-up for measuring data 13 detects a change of the amplitude 19 of the test signal when the wheel 12 is deformed due to transverse forces acting on the tire 15. The test signal is amplified by an electronic circuit integrated in the sensor and converted into an output signal. The operating point of the output signal of the pick-up for measuring data 13 that is responsive to the air slot 20 is adjusted in a determination unit 21 irrespective of the preadjustment. When the vehicle exhibits a stationary driving behavior, the output signal is standardized to a nominal value, and the nominal value is correlated to the zero point of the transverse force by way of means 21. Subsequently, there is a reproducible correlation between the variation of the amplitude signal and the variation of the transverse force.

The sinusoidal output signal which is produced by the effect of the encoder 17 at the magnetic-field-sensitive pick-up for measuring data 13 and the peak value of which varies with the air slot 20 may be an alternating voltage signal or an alternating current signal. The alternating current signal can be transformed into an alternating voltage signal in a signal-conditioning device associated with the pick-up for measuring data 13. Figures 3 and 4 show the correlation between the air slot 20 and the amplitude signal of the pick-up for measuring data 13, namely in a non-linear, almost exponential, form. The voltage of the output signal (sensor voltage) is plotted against the air slot 20 in Figure 2, while the output signal, cleared from direct voltage and signs, is plotted against the air slot in Figure 3.

The operation of the method of the present invention is as follows:

After the start of the motor vehicle, the driving behavior is determined with signals of conventional sensors, such as transverse acceleration and longitudinal acceleration sensors, yaw rate sensors, steering angle sensors and like elements, because the adaption of the amplitude signal to the air slot 20 shall take place under stationary conditions only. To detect a stationary driving behavior free from longitudinal and/or transverse forces, it is preferred that the following conditions are satisfied:

|transverse acceleration|< 0.07g

|longitudinal acceleration|< 0.1g

|steering angle|< 1°

|steering angle velocity| < 20[degree/s]

forward driving

gearshift-dependent speed

- first gear <10 km/h
- second gear <30 km/h
- third gear <50 km/h
- fourth gear <100 km/h
- fifth gear <150 km/h.

When these conditions are satisfied and remain stable for roughly 70 msec, a stationary driving behavior free from longitudinal or transverse forces prevails. The amplitude signal is then standardized to a nominal value with each peak value of the half wave or with each alternation of the magnetic areas N, S or poles or markings of the encoder 17. This nominal value is correlated with a zero point of the transverse force or force offset which was determined one time almost synchronously by a force measuring element, preferably a

measuring wheel rim, under the influence of the forces that occur on wheel 12. The value of the transverse force is ideally 0 Newton when the driving behavior is stationary.

Starting from the standardized nominal value of the amplitude signal, which value is correlated with the force offset, the transverse forces during dynamic conditions of the vehicle are determined in dependence on the amplitude variations $Amp_{usefuleffect}$ according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{useful\ effect}$ = ratio between the amplitude and the standardized nominal amplitude. In addition, the amplitude variations may be attributed to changes in distance according to the relation

$$\mathrm{Dis}_{\text{useful effect}} = \mathrm{k} * \ln\left(\frac{Amp}{Amp_{nom.\ value}}\right) = \mathrm{k} * (\ln(Amp) - \ln(Amp_{nom.value})) = \mathrm{k} * \ln(Amp) - \text{nominal distance}$$

by means of the inverse function of the dependence of the amplitude on the air slot, wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant which is determined from the characteristic curve of the sensor according to Figure 4.

The transverse forces may then be determined basically as a function of the changes in distance.

Patent Claims:

1. Method for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire,
c h a r a c t e r i z e d in that the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device is set irrespective of the preadjustment of the said point which was made during predetermined driving behavior.

2. Method as claimed in claim 1,
c h a r a c t e r i z e d in that the output signal is standardized to at least one nominal value when the driving behavior is stationary.

3. Method as claimed in claim 1 or 2,
c h a r a c t e r i z e d in that the output signal is a sinusoidal alternating voltage or alternating current signal, and the nominal value is determined with each peak value of the half wave (amplitude) or with each alternation of the poles or markings of the encoder.

4. Method as claimed in any one of claims 1 to 3,
c h a r a c t e r i z e d in that associated with the nominal value is a value which reproduces the zero point (offset) of the transverse force acting on the wheel and/or the tire.

5. Method as claimed in any one of claims 1 to 4, c h a r a c t e r i z e d in that the transverse forces are determined in dependence on the amplitude variations according to the relation

$$Amp_{usefuleffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude.

6. Method as claimed in claim 5, c h a r a c t e r i z e d in that the amplitude variations are attributed by means of the inverse function to changes in distance according to the relation

$$Dis_{usefuleffect} = k * \ln\left(\frac{Amp}{Amp_{no\min alvalue}}\right)$$

wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant.

7. Method as claimed in claim 6, c h a r a c t e r i z e d in that the transverse forces are basically determined as a function of the changes in distance.

8. Method as claimed in any one of claims 1 to 7, c h a r a c t e r i z e d in that the nominal value is maintained until the predetermined driving behavior is detected.

9. Control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire, c h a r a c t e r i z e d by a determination unit which sets the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device irrespective of the said point's preadjustment which was made during predetermined driving behavior.

10. Control circuit as claimed in claim 9, c h a r a c t e r i z e d by a standardization of the output signal to at least one nominal value when the vehicle movement behavior is stationary.

11. Control circuit as claimed in claim 9 or 10, c h a r a c t e r i z e d in that the output signal of the pick-up for measuring data or the signal-evaluating device is a sinusoidal alternating voltage or alternating current signal, and the determination unit determines the nominal value with each peak value of the half wave (amplitude) or with each alternation of the poles or markings of the encoder.

12. Control circuit as claimed in any one of claims 9 to 11, c h a r a c t e r i z e d in that there is provision of means attributing a value to the nominal value which represents the zero point (offset) of the transverse force, and in that the determination unit determines

transverse forces in dependence on the amplitude variations according to the relation

$$Amp_{usefulefffect} = \frac{Amp}{Amp_{no\min alvalue}}$$

wherein Amp = output signal (amplitude), $Amp_{nominal\ value}$ = standardized output signal (nominal value), $Amp_{usefuleffect}$ = ratio between the amplitude and the standardized nominal amplitude.

13. Control circuit as claimed in claim 12, c h a r a c t e r i z e d in that the determination unit attributes the amplitude variations by means of an inverse function to changes in distance according to the relation

$$Dis_{usefuleffect} = k * \ln\left(\frac{Amp}{Amp_{no\min alvalue}}\right)$$

wherein $Dis_{useful\ effect}$ = changes in distance and k = negative constant.

Abstract:

Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

The present invention relates to a method and a control circuit for detecting and evaluating the conditions of vehicle movement dynamics for a motor vehicle by means of wheel force sensors, preferably tire sensors, which take the preadjusted air slot between at least one rotating encoder and at least one pick-up for measuring data into account as a standard for the transverse forces that act on the wheel or on the tire. In order to reduce the errors in the evaluation of wheel forces, especially of deformations of the wheel rim and/or the tire detected by means of tire sensors, the air-slot-dependent operating point of the output signal of the pick-up for measuring data or a signal-conditioning device is set irrespective of the preadjustment of the said point which was made during predetermined driving behavior.

(Figure 3)

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# Erklärung für Patentanmeldungen mit Vollmacht

## German Language Declaration

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☒ wurde angemeldet am 14.09.2000
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Ich bestätige hiermit, daß ich den Inhalt der oben angegebenen Patentanmeldung, einschließlich der Ansprüche, die durch einen oben erwähnten Zusatzantrag und in einem „preliminary amendment" abgeändert wurden, durchgesehen und verstanden habe.

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As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Method for Detecting and Evaluating the Conditions of Vehicle Movement Dynamics for a Motor Vehicle

the specification of which is attached hereto unless the following box is checked:

☒ was filed on 14.09.2000
as United States Application Number or PCT International Application Number
PCT/EP00/08989

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above and as amended in a preliminary amendment.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.



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Prior Foreign Applications
(Frühere ausländische Anmeldungen)

| | | | Priority Not Claimed<br>Priorität nicht beansprucht |
|---|---|---|---|
| **19944098.0** | **Germany** | 15/September/1999 | ☐ |
| **10026111.6** | **Germany** | 26/May/2000 | |
| **10044291.9** | **Germany** | 07/September/2000 | ☐ |
| **PCT/EP 0008989** | **PCT** | 14/September/2000 | |

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